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This month's MuseLetter is in two parts. The first is an essay which I wrote recently for Yes! Magazine, "100% Renewable Energy: What We Can Do in 10 Years," in which I take a pragmatic look at what energy transition might be achieved in the US if we really put our minds to it. That's followed by a second piece, which consists of reviews of two important new books.

100% Renewable Energy: What We Can Do in 10 Years

If our transition to renewable energy is successful, we will achieve savings in the ongoing energy expenditures needed for economic production. We will be rewarded with a quality of life that is acceptable—and, perhaps, preferable to our current one (even though, for most Americans, material consumption will be scaled back from its current unsustainable level). We will have a much more stable climate than would otherwise be the case. And we will see greatly reduced health and environmental impacts from energy production activities.

But the transition will entail costs—not just money and regulation, but also changes in our behavior and expectations. It will probably take at least three or four decades, and will fundamentally change the way we live.

Nobody knows how to accomplish the transition in detail, because this has never been done before. Most previous energy transitions were driven by opportunity, not policy. And they were usually additive, with new energy resources piling onto old ones (we still use firewood, even though we've added coal, hydro, oil, natural gas, and nuclear to the mix).

Since the renewable energy revolution will require trading our currently dominant energy sources (fossil fuels) for alternative ones (mostly wind, solar, hydro, geothermal, and biomass) that have different characteristics, there are likely to be some hefty challenges along the way.

Therefore, it makes sense to start with the low-hanging fruit and with a plan in place, then revise our plan frequently as we gain practical experience. Several organizations have already formulated plans for transitioning to 100 percent renewable energy. David Fridley, staff scientist of the energy analysis program at the Lawrence Berkeley National Laboratory, and I have been working for the past few months to analyze and assess those plans and have a book in the works titled *Our Renewable Future*. Here's a very short summary, tailored mostly to the United States, of what we've found.

Level One: The Easy Stuff

Nearly everyone agrees that the easiest way to kick-start the transition would be to replace coal with solar and wind power for electricity generation. That would require building lots of panels and turbines while regulating coal out of existence. Distributed generation and storage (rooftop solar panels with home- or business-scale battery packs) will help. Replacing natural gas will be harder, because gas-fired "peaking" plants are often used to buffer the intermittency of industrial-scale wind and solar inputs to the grid (see Level Two).

Electricity accounts for less than a quarter of all final energy used in the United States. What about the rest of the energy we depend on? Since solar and wind produce electricity, it makes sense to electrify as much of our energy usage as we can. For example, we could heat and cool most buildings with electric air-source heat pumps, replacing natural gas- or oil-fueled furnaces. We could also begin switching out all our gas cooking stoves for electric stoves.

Transportation represents a large swath of energy consumption, and personal automobiles account for most of that. We could reduce oil consumption substantially if we all drove electric cars (replacing 250 million gasoline-fueled automobiles will take time and money, but will eventually result in energy and financial savings). Promoting walking, bicycling, and public transit will take much less time and investment.

Buildings will require substantial retrofitting for energy efficiency (this will again take time and investment, but will offer still more opportunities for savings). Building codes should be strengthened to require net-zero-energy or near-net-zero-energy performance for new construction. More energy-efficient appliances will also help.

The food system is a big energy consumer, with fossil fuels used in the manufacture of fertilizers, food processing, and transportation. We could reduce a lot of that fuel consumption by increasing the market share of organic local foods. While we're at it, we could begin sequestering enormous amounts of atmospheric carbon in topsoil by promoting farming practices that build soil rather than deplete it—as is being done, for example, in the Marin Carbon Project.

If we got a good start in all these areas, we could achieve at least a 40 percent reduction in carbon emissions in 10 to 20 years.

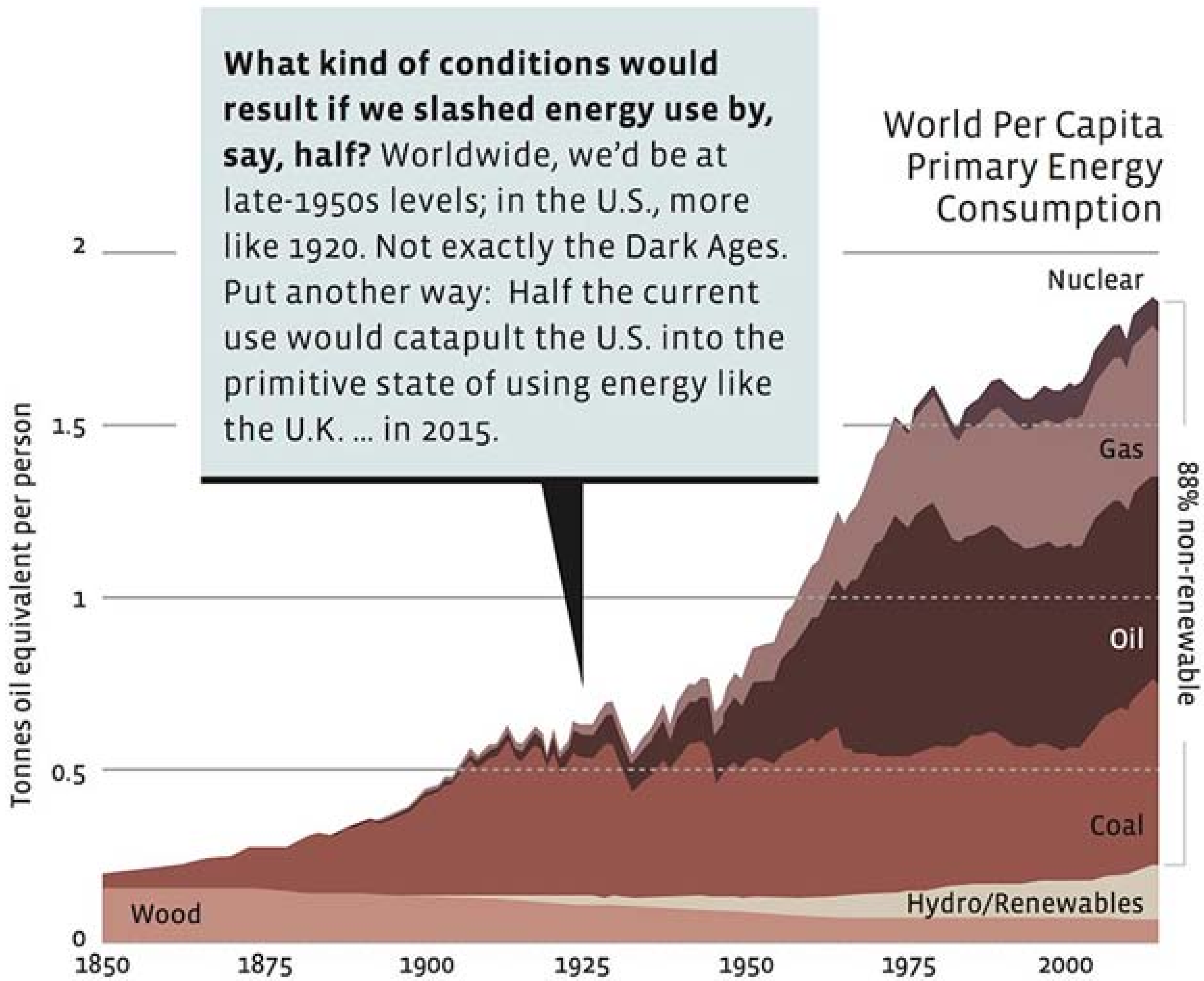
Level Two: The Harder Stuff

Solar and wind technologies have a drawback: They provide energy intermittently. When they become dominant in our overall energy mix, we will have to accommodate that intermittency in various ways. We'll need substantial amounts of grid-level energy storage as well as a major grid overhaul to get the electricity sector close to 100 percent renewables (replacing natural gas in electricity generation). We'll also need to start timing our energy usage to coincide with the availability of sunlight and wind energy. That in itself will present both technological and behavioral hurdles.

After we switch to electric cars, the rest of the transport sector will require longer-term and sometimes more expensive substitutions. We could reduce our need for cars (which require a lot of energy for their manufacture and decommissioning) by increasing the density of our cities and suburbs and reorienting them to public transit, bicycling, and walking. We could electrify all motorized human transport by building more electrified public transit and intercity passenger rail lines. Heavy trucks could run on fuel cells, but it would be better to minimize trucking by expanding freight rail. Transport by ship could employ sails to increase fuel efficiency (this is already being done on a tiny scale by the MS Beluga Skysails, a commercial container cargo ship partially powered by a 1,700-square-foot, computer-controlled kite), but relocalization or deglobalization of manufacturing would be a necessary co-strategy to reduce the need for shipping.

Much of the manufacturing sector already runs on electricity, but there are exceptions—and some of these will offer significant challenges. Many raw materials for manufacturing processes either are fossil fuels (feedstocks for plastics and other petrochemical-based materials) or require fossil fuels for mining or transformation (e.g., most metals). Considerable effort will be needed to replace fossil-fuel-based industrial materials and to recycle non-renewable materials more completely, significantly reducing the need for mining.

If we did all these things, while also building far, far more solar panels and wind turbines, we could achieve roughly an 80 percent reduction in emissions compared to our current level.



World per capita primary energy consumption Sources: Research from Peter Kalmus and Post Carbon Institute YES! Magazine infographic, 2016

Level Three: The Really Hard Stuff

Doing away with the last 20 percent of our current fossil-fuel consumption is going to take still more time, research, and investment—as well as much more behavioral adaptation.

Just one example: We currently use enormous amounts of concrete for all kinds of construction. The crucial ingredient in concrete is cement. Cement-making requires high heat, which could theoretically be supplied by sunlight, electricity, or hydrogen—but that will entail a nearly complete redesign of the process.

While with Level One we began a shift in food systems by promoting local organic food, driving carbon emissions down further will require finishing that job by making all food production organic, and requiring all agriculture to build topsoil rather than deplete it. Eliminating all fossil fuels in food systems will also entail a substantial redesign of those systems to minimize processing, packaging, and transport.

The communications sector—which uses mining and high-heat processes for the production of phones, computers, servers, wires, photo-optic cables, cell towers, and more—presents some really knotty problems. The only good long-term solution in this sector is to make devices that are built to last a very long time and then to repair them and fully recycle and remanufacture them when absolutely needed. The Internet could be maintained via the kinds of low-tech, asynchronous networks now being pioneered in poor nations, using relatively little power. An example might be the AirJaldi networks in India, which provide Internet access to about 20,000 remote users in six states, using mostly solar power.

Back in the transport sector: We've already made shipping more efficient with sails, but doing away with petroleum altogether will require costly substitutes (fuel cells or biofuels). One way or another, global trade will have to shrink.

There is no good drop-in substitute for aviation fuels; we may have to write off aviation as anything but a specialty transport mode. Planes running on hydrogen or biofuels are an expensive possibility, as are dirigibles filled with (non-renewable) helium, any of which could help us maintain vestiges of air travel. Paving and repairing roads without oil-based asphalt is possible, but will require an almost complete redesign of processes and equipment.

Great attention will have to be given to the interdependent linkages and supply chains connecting various sectors (communications, mining, and transport knit together most of what we do in industrial societies). Some links in supply chains will be hard to substitute, and chains can be brittle: A problem with even one link can imperil the entire chain.

The good news is that if we do all these things, we can get beyond zero carbon emissions; that is, with sequestration of carbon in soils and forests, we could actually reduce atmospheric carbon with each passing year.

Doing Our Level Best

This plan features "levels"; the more obvious word choice would have been "stages." The latter implies a sequence—starting with Stage One, ending with Stage Three—yet accomplishing the energy transition quickly will require accelerating research and development to address many Level Two and Three issues at the same time we're moving rapidly forward on Level One tasks. For planning purposes, it's useful to know what can be done relatively quickly and cheaply, and what will take long, expensive, sustained effort.

How much energy will be available to us at the end of the transition? It's hard to say, as there are many variables, including rates of investment and the capabilities of renewable energy technology without fossil fuels to back them up and to power their manufacture, at least in the early stages. This "how much" question reflects the understandable concern to maintain current levels of comfort and convenience as we switch energy sources. But in this regard, it is good to keep ecological footprint analysis in mind.

According to the Global Footprint Network's Living Planet Report 2014, the amount of productive land and sea available to each person on Earth in order to live in a way that's ecologically sustainable is 1.7 global hectares. The current per capita ecological footprint in the United States is 6.8 global hectares. Asking whether renewable energy could enable Americans to maintain their current lifestyle is therefore equivalent to asking whether renewable energy can keep us living unsustainably. The clear answer is: only temporarily, if at all. So why bother trying? We should aim for a sustainable level of energy and material consumption, which on average is significantly lower than at present.

One way or another, the energy transition will represent an enormous societal shift. During past shifts, there were winners and losers. In the current instance, if we don't pay great attention to equity issues, it is entirely possible that only the rich will have access to renewable energy, and therefore, ultimately, to any substantial amounts of energy at all.

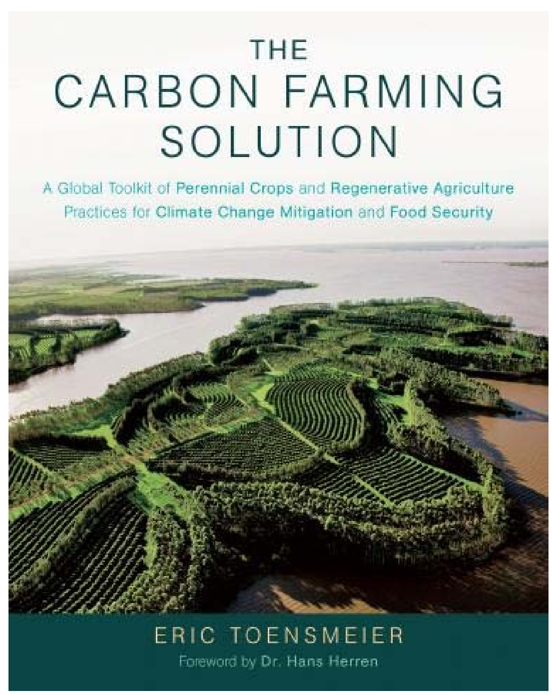
The collective weight of these challenges and opportunities suggests that a truly all-renewable economy may be very different from the American economy we know today. The renewable economy will likely be slower and more local; it will probably be a conserver economy rather than a consumer economy. It will also likely feature far less economic inequality. Economic growth may reverse itself as per capita consumption shrinks; if we are to avert a financial crash and perhaps a revolution as well, we may need a different economic organizing principle. In her recent book on climate change, *This Changes Everything*, Naomi Klein asks whether capitalism can be preserved in the era of climate change. While it probably can (capitalism needs profit more than growth), that may not be a good idea because, in the absence of overall growth, profits for some will have to come at a cost to everyone else.

This short article only addresses the energy transition in the United States; other nations will face different challenges and opportunities. Poor nations will have to find ways to provide all their energy from renewable sources while advancing in terms of the U.N. Human Development Index. Nations especially vulnerable to sea level rise may have other immediate priorities to deal with. And nations with low populations but very large solar or wind resources may find themselves in an advantageous position if they are able to obtain foreign investment capital without too many strings attached.

The most important thing to understand about the energy transition is that it's not optional. Delay would be fatal. It's time to make a plan—however sketchy, however challenging—and run with it, revising it as we go.

Two Important New Books

The Carbon Farming Solution: A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Mitigation and Food Security, **by Eric Toensmeier (Chelsea Green)**



Among systems thinkers there is already a fairly robust literature on the use of agroecology to capture and sequester atmospheric carbon. From its origins in the late 1970s, Permaculture has sounded this theme; more recently, Vandana Shiva's book *Soil Not Oil* (Women Unlimited Books, 2009) honed the discourse about the adverse climate impacts of conventional agriculture and the potential of regenerative agriculture to reverse those impacts. A well-attended "Soil Not Oil" international conference held in Oakland in September 2015 (another is scheduled for later this year) brought together advocates and researchers to discuss the new field of carbon farming.

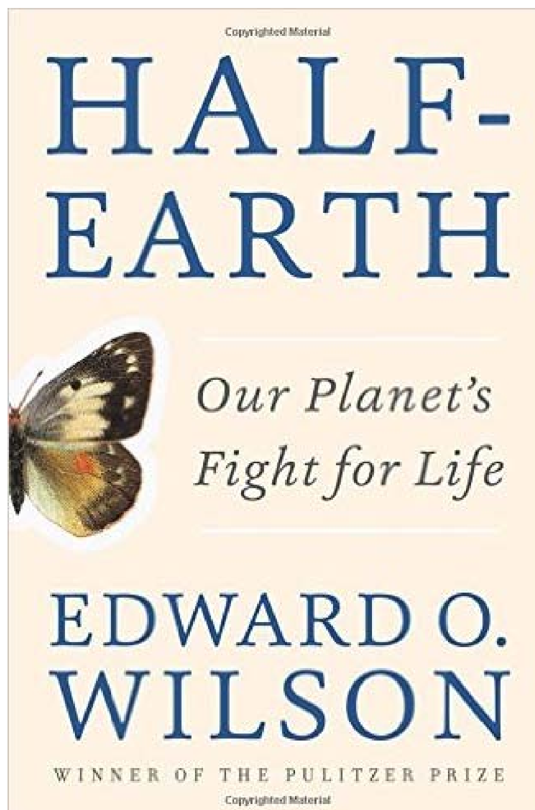
Toensmeier's book aims to be the bible of this new movement, and it does indeed competently cover the wide range of issues related to carbon sequestration in soils, forests, and perennial crops. Yet even though it's a big book (about 500 large-format pages, with color photos and graphics, as well as topical sidebars), it would be impossible to fully explore the wide range of relevant subjects within a single volume. Veterans of the Permaculture literature will find some familiar ground re-trod here, while advocates of biochar may wince when they see that their favored climate solution is granted only a few paragraphs of discussion.

Nevertheless, this is a timely and useful book. As its author carefully explains in the first few chapters, carbon sequestration in the biosphere is our only credible path to reducing atmospheric carbon dioxide concentrations. But only a revolution in agricultural practices can enable us to take advantage of this potential. Toensmeier is careful to point out repeatedly that carbon farming cannot by itself solve the climate crisis: the world simply must rapidly reduce the use of fossil fuels—which will entail not only the build-out of renewable energy technologies, but also the redesign of industrial systems for manufacturing and transport.

The mainstream climate mitigation prescription includes carbon capture and storage (burning coal but burying the CO2), but that is an economically and practically unrealistic strategy. Carbon farming makes far more sense: not only is there plenty of capacity in the soil for carbon uptake, but the agricultural practices required would address many other problems at the same time—including the economic viability of small-scale farming, biodiversity loss, the restoration of water and nutrient cycles, food security, and toxic chemical pollution throughout the biosphere.

Carbon farming is clearly an idea whose time has come, and Eric Toensmeier is a forceful, knowledgeable, and eloquent advocate.

Half-Earth: Our Planet's Fight for Life, **by E. O. Wilson (Liveright Books)**



Edward O. Wilson's latest book again advances an idea that is far from new—in this case, that of setting aside massive amounts of land and ocean for ecosystem recovery so as to stem biodiversity loss.

The goal of creating national parks immune to industrial development dates back to the mid-19th century, with John Muir and Theodore Roosevelt its most famous proponents. Since 1991, Earth First! founder Dave Foreman has been working with the Wildlands Project to establish a network of protected wilderness areas across North America. And throughout the past couple of decades, philanthropist Doug Tompkins (who tragically died last December) financed and created a series of huge wilderness preserves in South America.

The need for such efforts could hardly be plainer. As Elizabeth Kolbert documented in her chilling book *The Sixth Extinction* (Henry Holt, 2014), we humans are causing so many other species to disappear (and the rate is at which this is happening is increasing so fast), that the phenomenon can only be compared to the very few most cataclysmic events in all of Earth's prior history.

Wilson argues that if we are to slow the rate of extinctions, we must do two things: cut back dramatically on the activities that are making it difficult for other species to survive (burning fossil fuels, cutting ancient forests, polluting waterways, expanding human populations), and create large interconnected spaces where nature can regenerate. His bold proposal is to devote fully half the Earth's surface (land and water) to nature.

An obvious problem: regardless what we do now, we humans have already emitted enough carbon to guarantee a certain amount of climate change, and zones where species currently thrive may not be places where they will be able to persist in a warmer future. Therefore isolated nature preserves will not suffice; wildlife corridors will also be needed. And many of the preserves must be very large in order to be of use: a huge number of small nature parks would support far fewer species in total.

Wilson's idea of setting aside half the Earth for other species may seem like a tall order, but 15 percent of the planet has already been protected with national parks and other preserves, and most of the needed legal and regulatory mechanisms have already been developed and tested. The author identifies specific spots where Earth's biodiversity can still be reclaimed and shows that the project is practically achievable, if admittedly ambitious. All we need is the will.

Wilson's proposal has already been attacked by "humanitarians" arguing that concern over human overpopulation is essentially racist, and that areas that are centers of eroding biodiversity are also places where poor people need access to resources. These are specious arguments: if we do not protect biodiversity, it is precisely the poorest people in countries with the highest fertility rates who will suffer first and foremost. That said, it is clearly true that the cause of human equity should always be taken into account in conservation efforts.

Half-Earth is certainly not the first word on the subject of wilderness preservation and will hopefully not be the last. But the issue is reaching criticality, and Wilson's proposal is clear and bold. Further, the author is a revered biologist and beloved naturalist whose acclaimed literary skills have never shone brighter.